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Godiva quadricolor (Barnard, 1927) (Nudibranchia: Facelinidae) spreads into southern Queensland

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ABSTRACT

The aeolid nudibranch *Godiva quadricolor* (Barnard, 1927), previously recorded as introduced into southern Western Australia (i.e., the Fremantle-Cockburn Sound area) and now probably naturalised there, is herein recorded from southern Queensland (i.e., Pumicestone Passage, immediately north of the Port of Brisbane), where a breeding population is presently established. The most likely source of both introductions is shipping. *Godiva quadricolor* originally extended naturally through (tropical) eastern and (temperate) south-eastern Africa, so its further spread around the Australian continent seems inevitable. This paper records the characters important for recognition of this species, corrects the author's earlier account of the morphology of the rhinophores, and describes intraspecific variation, particularly that relating to coloration of the head and cerata. *Godiva rachaelae* Rudman, 1980 is formally synonymised with *G. quadricolor*. *Godiva quadricolor* is now recorded as introduced in southern Western Australia, eastern Australia (herein), north-western Africa and the Mediterranean Sea, but it has never occurred naturally in the Indo-Pacific Ocean.

KEYWORDS: zoogeography, introduced marine species, shipping, *Godiva*, Queensland, Western Australia.

INTRODUCTION

Twelve species of opisthobranch molluscs are presently considered to have been accidentally introduced into Australian coastal waters by shipping; the majority are now definitely naturalised judging by persistence of records: *Aplysiopsis formosa* Pruvot-Fol (Hermaeidae), *Kaloplocamus ramosus* (Cantraine) (Triophidae), *Polycera capensis* Quoy and Gaimard (Polyceridae), *Polycera hedgpethi* Er. Marcus (Polyceridae), *Thecacera pennigera* (Montagu) (Polyceridae), *Okenia plana* Baba (Goniodorididae), *Okenia zoobotryon* (Smallwood) (Goniodorididae), *Aegires punctilucens* (d'Orbigny) (Aegiridae), *Onchidoris depressa* (Alder and Hancock) (Onchidorididae), *Eubranchus inabai* Baba (Eubranchidae), *Tenellia adspersa* (Nordmann) (Tergipedidae), *Godiva quadricolor* (Barnard) (Facelinidae) (pers. obs.). Arguably the latter is the best documented because it was the subject of a paper (Willan 1987) documenting its discovery in 1980 in the Fremantle-Cockburn Sound area, and that work provided a complete anatomical description to enable its future recognition. This contribution records *G. quadricolor* from the other side of the continent (i.e., southern Queensland), describes intra-specific variability and corrects the author's earlier account of the morphology of the rhinophores.

MATERIAL STUDIED

Mr Gary Cobb of Buderim, Queensland, Australia, recorded the following 12 animals of *Godiva quadricolor* in 5–6 m off Bulloek Beach at the northern reach of Pumicestone Passage, southern Queensland (centered on 26°48.50'S, 153°08.50'E): seven specimens – 58 mm, 36 mm, 35 mm extended length (remaining four animals not measured), on 6 October 2004; one specimen – 30 mm, on 9 October 2004; four specimens – 54 mm, 51 mm, 50 mm and 34 mm, on 23 October 2004. Eight of these 12 animals were collected and photographed in the laboratory (the strong current in Pumicestone Passage prevented them being photographed *in situ*). The first three animals were found close to each other on a 2 m^2 patch of clean, coarse sand. They were preserved and sent to the author for study and they are now accessioned into the wet mollusc collection at the Museum and Art Gallery of the Northern Territory (NTM) under the registration number P28522. Before preservation, these three specimens laid egg masses in captivity and on subsequent dives in Pumicestone Passage (all dives there are drift dives of necessity), Mr Cobb noted numerous identical spawn masses. The remaining specimens were returned to the sea approximately one week after their capture.

TAXONOMY

Family Facelinidae Vayssière, 1888

Genus *Godiva* Macnae, 1954

The genus was redefined by Willan (1987: 80).

Godiva quadricolor Barnard, 1927

(Figs 1, 2)

Hervia quadricolor Barnard, 1927: 203, pl. 20, figs 9, 10.

Godiva quadricolor. – Macnae 1954: 23-25, text figs 23-25; Edmunds 1964: 26, 27; Lemche 1964: 56, 57; Baba and Hamatani 1965: 108, 109, Edmunds 1977: 302, 303; Rudman 1980: 160, 171; M. Branch and G. Branch 1981: colour pl. 123, text fig. 316; J. Garcia and F. Garcia 1984: 14; Willan 1987: 71-85; Wells and Bryce 1993: 162, species number 211; Debelius 1998: 310; Furlani 1996: unnumbered page; Furlani 1997: 7.

Godiva rachelae Rudman, 1980: 154-160, figs 10, 11, 12A, 13D, 14A, 15 (new synonym).

Facelina coronata. – Cattaneo-Vietti *et al.* 1990: pl. 13, fig. 4 (misidentification, not *Facelina coronata* (Forbes and Goodsir, 1839)).

Comments on synonomy. Cervera (2002) has pointed out that Cattaneo-Vietti *et al.* (1990) misidentified *Godiva quadricolor* as *Facelina coronata*.

The variation in body and cerata coloration displayed by the specimens from southern Queensland is within the limits of intraspecific variation known for *Godiva quadricolor*. Further, given that: (a) some of the present animals possess the identical colour pattern to that of the species previously known as *G. rachelae* Rudman, 1980 (see below, and Fig. 1B–D), (b) Rudman (1980: 160) found *G. rachelae* agreed with *G. quadricolor* in all features bar coloration and minor radular details, (c) variation is now known to exist in the number of denticles on the blade of the radular tooth (see below), and (d) the spawn masses of Tanzanian and southern Queensland animals are identical, I am confident *G. rachelae* is a synonym of *G. quadricolor*. Therefore, I formally make that synonymy herein.

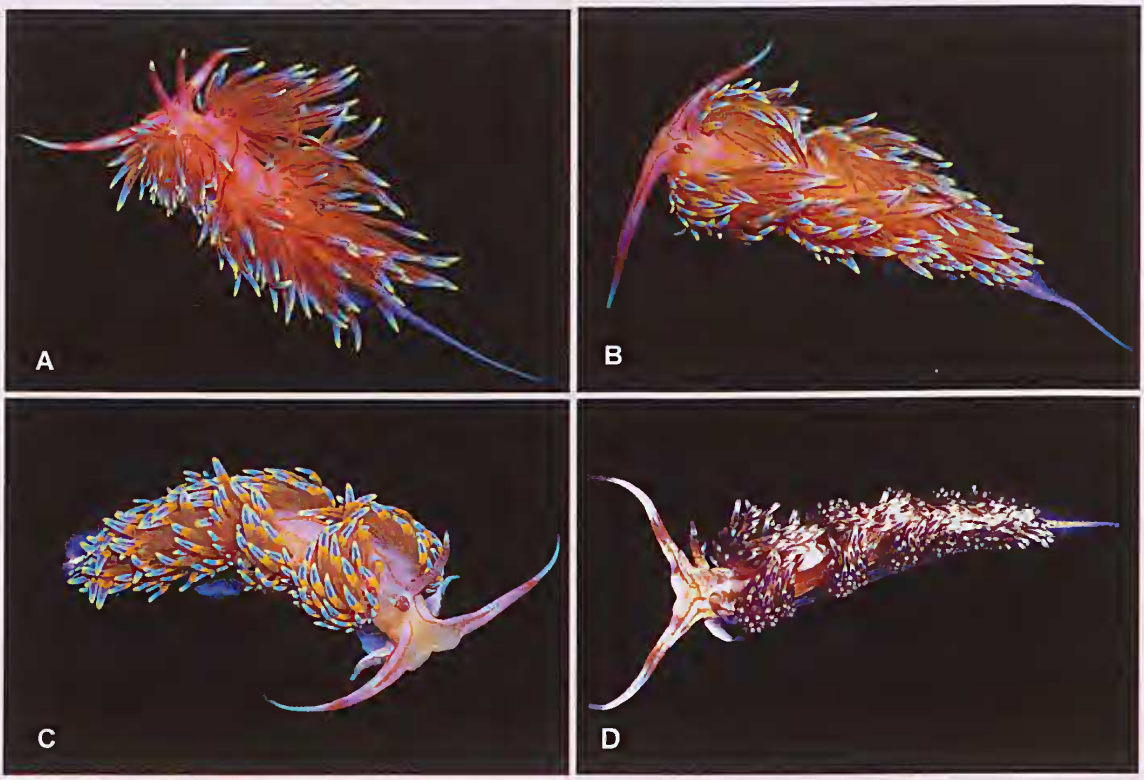

Fig. 1. *Godiva quadricolor*, colour forms from Australian and South African populations. **A**, 51 mm extended length, 5–6 m, Pumicestone Passage, southern Queensland, Australia, 23 October 2004, animal displaying "typical" coloration of form quadricolor. **B**, 40 mm extended length, 5–6 m, Pumicestone Passage, southern Queensland, Australia, 6 October 2004, animal displaying coloration of form rachelae. **C**, 35 mm extended length, 5–6 m, Pumicestone Passage, southern Queensland, Australia, 6 October 2004, animal displaying coloration of form rachelae. **D**, c. 25 mm extended length, low tide, Charles' Pool, Shaka's Rock, north of Durban, KwaZulu-Natal, South Africa, September 1985, animal displaying coloration of form rachelae. Photos: A–C, G. Cobb; D, D. Herbert.

CHARACTERISATION

External features. *Godiva quadricolor* is a striking and distinctive member of the family Facelinidae. There are now adequate descriptions and images available to render it easily recognisable: Macnae (1954) has provided a detailed account of the morphology of the species in South Africa (Gosliner 1980: 55), and Willan (1987) has done the same for specimens from south-western Australia. *Godiva quadricolor* is included in the Australian National Introduced Marine Pest Information System (NIMPIS 2002). Within Australian waters, there are no other aeolids that could easily be confused with *G. quadricolor*, even in the field. Externally it is characterised by its relatively long body (here reported to reach 58 mm, but 35 mm is usual for adults), tentaculate fronto-lateral corners of the foot (propodial tentacles), extremely long tail (one of the animals reported here had a body length of 40 mm, including an 18 mm long tail i.e., the tail was one-third of its total body length), elongate oral tentacles that are much longer than rhinophores, elongate and fusiform cerata arranged in symmetrical arches on either side of the midline apart from the posterior pairs which are in short oblique rows. The most distinctive elements of the coloration (extracted from Willan 1987) are: (a) two large, opaque white dorsal blotches or streaks, one immediately behind the head and the other over the pericardium; (b) a narrow cream streak extending mid-dorsally the full length of the tail; (c) a pale (most often pale blue) streak extending dorso-laterally from the base of each rhinophore to two-thirds of the distance along the oral tentacle progressively narrowing in width; and (d) four separate elements of colour on the cerata – cream cnidosae, followed by sky blue, chrome yellow, and brown proximally. Many authors have commented on the variability of the colour of the cerata; not so much in the presence or absence of the separate elements, but their extent. "All are variable in distribution and one or more may be reduced to a vestige or absent altogether" (Macnae 1954). All of the individuals from this Queensland population possessed a rose-brown background suffusion to the body – a hue recorded previously only in the animal from South Africa photographed by Branch and Branch (1981).

The rhinophores appear smooth to the naked eye. However, under magnification, they bear irregular annuli with a narrow ridge extending up the posterior midline (Fig. 2A, B) contradicting the author's previous description (Willan 1987: 72), based on only one preserved specimen with contracted rhinophores, of "numerous, tiny, low, flat pustules".

Two of the 12 individuals from southern Queensland had dark pigment on the head concentrated into stripes flanking, and thus outlining, the pale streak that ran from the base of each rhinophore onto the oral tentacle (Fig. 1B,C), but the other ten had no such outlining stripe (Fig. 1A). The striping pattern on the oral tentacles is consistent with that described for *Godiva rachelae*, here recognised as a colour form of *G. quadricolor*. An animal from South Africa possessing the coloration of the form rachelae is illustrated in Fig. 1D.

Internal features. The radula consists of a row of about 30 teeth: each tooth has a highly arched basal plate, the cusp is protracted and broad, and it is flanked by three to six (exceptionally seven or eight) strong yet narrow denticles. The masticatory process on the jaw is relatively short and thin, and its dorsal margin possesses a single row of tall, cuticularised denticles. The reproductive system, uniquely in the family, possesses a sharp-pointed, curved, cuticular spine (characters extracted from Willan 1987). The penial spine and ornamentation on the masticatory elements of the jaws offer a suite of characters which, in cladistics terminology, can be considered as autapomorphies for the genus *Godiva* (Willan 1987).

Fig. 2. *Godiva quadricolor* from Pumicestone Passage, southern Queensland, 36 mm extended length, detail of fully extended rhinophores of actively crawling animal: **A**, Lateral view; **B**, Posterior view. Scale bar = 2 mm. Photos: G. Cobb.

Diet. *Godiva quadricolor* is a very active and pugnacious aeolid that readily 'bristles' its cerata when disturbed (Fig. 1A), autotomises the cerata with little provocation, and 'swims' briefly when aggravated by violent lateral flexion of the body. It is notorious for its diet in captivity (we know nothing of its diet in the wild); individuals voraciously consuming other nudibranchs (Gosliner 1987) (the specimens reported here from southern Queensland readily ate the nudibranchs *Lomanotus* sp. (see Cobb 2004) and *Pteraeolidia ianthina* (Angas)). Indeed, they seemed willing to devour any soft meat, natural or otherwise. Branch and Branch (1981: 220) presented a photograph of an animal eating the sea anemone *Anthothoe stimpsoni*, so the diet is not restricted exclusively to other nudibranchs. Mr Cobb discovered the specimens from Pumicestone Passage would readily devour mince and chicken in his aquarium.

COMPARISON WITH RELATED SPECIES

In the genus *Godiva* (*sensu* Willan 1987), most anatomical features are very similar, and this is fairly normal in aeolid groups where we would expect species of the same genus to have a very similar anatomy. It is important to be able to distinguish *G. quadricolor* from related (congeneric) Indo-Pacific species, none of which appears to have a human-assisted distribution at this time. Gosliner (1980, 1987) has recognised one new species of *Godiva* from Hawaii and separated it on its coloration. That species has a white streak along the front edge of the foot and propodial tentacles and a more or less continuous blue line bordering the foot. The tail has a white mid-dorsal streak on its upper surface. The rhinophores are banded in orange-brown and cream. The body is translucent with nebulous pale blue patches. The translucent cerata have scattered pigmentation consisting of creamish white pigment, as diffuse yet broad rings, over their outer surface. The chocolate brown digestive diverticulum is straight and narrow, and it tapers gradually to an exceedingly fine distal extremity. The author is currently describing another new Indo-Pacific species (see Wells and Bryce 1993: 157, species number 203 and Debelius 1996: 308) that has an orange mid-dorsal stripe on the oral tentacles and orange stripes on the head. And finally, a photograph of the specimen that Rudman (1980) mentioned (but did not illustrate) from 43 m, Broadhurst Reef, Great Barrier Reef, northern Queensland, shows that animal has a brown patch on the top of the head, a single narrow brown stripe that extends from the anteriormost ceratal cluster, along the side of the head onto the oral tentacle, and the cerata have two brown sections but neither blue nor orange colour elements, so that animal represents yet another new species; it is clearly not *G. quadricolor* (as herein interpreted) or its synonym *G. rachelae*.

ZOOGEOGRAPHY

Natural distribution. *Godiva quadricolor* was first recorded from St James, False Bay, South Africa (Barnard 1927) and it has subsequently been reported from many other localities on the east coast of South Africa (i.e., Kalk Bay, False Bay, Fish Hoek Bay, Schoenmakers Kop, Zwartkops River estuary, Richmond (Macnae 1954), Bloubergstrand, Richmond, Knysna, Tsitsikama National Park, Port Elizabeth (Gosliner 1987), KwaZulu-Natal (Fraser 2001) and KwaZulu-Natal north coast (D. Herbert pers. comm.)). Besides these localities in warm temperate South Africa, it has also been reported from tropical waters of the Mozambique coast (Edmunds 1977), and the synonymy with *G. rachelae* (see above) indicates that it occurs as far north as Dar es Salaam in central Tanzania. Presumably the populations throughout this extensive range on the central- and south-eastern coast are kept in genetic contact by the Agulhas Current, "the mightiest current bathing the South African coast, and brings warm water from the tropics to the east coast" (Branch and Branch 1981: 14). This extensive range is not uncommon for eastern African nudibranchs (Gosliner 1987) and it parallels that of other wide-ranging temperate-tropical aeolids like *Hermissenda crassicornis* (Eschscholtz), another facelinid, that ranges naturally from Wakasa Bay, northern Japan, to Kodiak Island, Alaska, to Punta Eugenia, México, and to Puertecitos, Bahia de Los Angeles, Baja California, México (Behrens 1991; D. Behrens pers. comm.). If it seems I have belaboured this extensive natural warm temperate-tropical distribution of *G. quadricolor* it is to alter the mindset of malacologists that the species is endemic to cool temperate South Africa because it was first described from there. As Willan (1976) has argued, the locality from which a species was originally described is not necessarily the centre of its natural distribution.

What is now clear is that *Godiva quadricolor* never occurred naturally further afield in the Indo-Pacific Ocean. Edmunds (1977: 303) was perfectly correct in stating: "It is such a large and gaudily coloured eolid that if it occurs commonly throughout the Indo-Pacific region it would almost certainly have been discovered there by now". Although nudibranchs are notoriously rare in time and space (Marshall and Willan 1999), there has been sufficient intensive collecting in this region nowadays in localities such as southern Japan, the Marianas Islands, Singapore, the Philippines, Papua New Guinea, New Caledonia, northern Australia, the Marshall Islands and Fiji, that such a large and striking aeolid could not have gone unnoticed.

Human-assisted spread. In recording *Godiva quadricolor* on a boat hull in Ghana, Edmunds (1977) made two important revelations. First was the

documentation of its ability to live as part of the fouling community on boat hulls, and thus flag its potential for widespread transport. Second was the recognition that *G. quadricolor* can indeed live in tropical waters, a faet not highlighted by Edmunds himself. There have been no further records of *G. quadricolor* from tropical western Afriea, but this is not surprising because there is no research being undertaken on nudibranchs from this part of the world at the present time.

Willan (1987) recorded *Godiva quadricolor* as being established in southern Western Australia. He documented 14 animals from the Fremantle-Coekburn Sound area that were either collected or photographed between 1980 and 1983. The most probable explanation for this population was an aeeidental introduetion by shipping, but in deference to the views of some Australian malacologists, the possibility of a natural extension of range across the Indian Ocean was also left open. Thc hypothesis of introduetion by shipping has been repeated by Wells and Bryce (1993), Furlani (1996) and Debelius (1998) when they have subsequently illustrated animals from Western Australia. Graham Edgar discovered three animals on a sand pateh close to a elump of seagrass (*Poisidonia australis*) in 3 m, near the causeway in Cockburn Sound on 12 January 1991. The survey by CRIMP for introduced speeies at the Port of Fremantle and the adjaeent eoast in 1999 did not reeord *G. quadricolor* (CRIMP 2000), but that survey was intended to look for speeies already designated as marine pests on the Australian Ballast Water Management Advisory Committee target list and the sampling was inadequate as a eomprehensive faunal survey; indeed only 14 species of gastropod and no nudibranchs were reeorded. Abadi (2003) found and photographed *G. quadricolor* on a sandy-muddy substrate in 13 m, in the Swan River, on 22 December 2003. Therefore, in the author's opinion, the evidcnee points strongly towards the naturalisation of *G. quadricolor* in southern Western Australia.

Cattaneo-Vietti *et al.* (1990) ineluded a picture of *Godiva quadricolor* (which they misidentified as *Facelina coronata*) in their book on Mediterranean nudibranchs. The loeation is very signifieant because Fusaro Lake is a highly modified water body near Naples eontaining many other alien species like *Polycera hedgpethi*. This record is a first for the Mediterranean and the author does not know whether *G. quadricolor* had become naturalised there or not.

Thc present discovery of an established breeding population of *Godiva quadricolor* in southern Queensland surely vindicates the hypothesis of human-assisted spread of this nudibranch. Mr Cobb recorded 12 individuals and many spawn masses over only 18 days in October 2004. The oeeurrence of *G. quadricolor* at this loeality in southern Queensland is not surprising, since Pumicestone Passage is immediately beside the main shipping route into Moreton Bay, and thence the Port of Brisbane. I prediet this southern Queensland population will persist and the speeies will beeome naturalised in eastern Australia as it is presently naturalised in south-western Australia.

In conclusion it would seem that *Godiva quadricolor* originally had an extensive natural distribution in (tropical and temperate waters of) central and southern East Africa, and now, with the aid of shipping, it is spreading rapidly around the world; it is certainly spreading more rapidly within Australia at this time than any of the other alien opisthobranch speeies.

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